IDENTIFYING AND IMPROVING STUDENTS' MENTAL MODELS OF TOOTH DECAY

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The aims of this study were to identify the initial mental models of tooth decay among a sample of 15-16 year-old Spanish students, and then to analyse changes in these models following the students' participation in a teaching sequence on this topic. The study focuses on the analysis of two tasks that formed part of a pre-test/post-test design whose aim was to determine whether students could provide an adequate explanation of the problem of dental caries. Mental models were identified through an iterative process that combined an examination of the nature of the concept in question with an analysis of students' responses. Five mental models of tooth decay were identified. Three of them were associated with a single active agent (the tooth, food or microscopic living organisms). The fourth model included sugar plus a second active agent, while the active agent in the fifth model was acids. We also identified four mechanisms, which were not exclusive to any one model. The results showed an evolution in students' explanatory models of tooth decay following their participation in the teaching sequence. Initially, the majority of students used simple models involving a single active agent, whereas by the end of the teaching sequence the majority of them were employing the most advanced models. However, formulating the mechanism through which tooth decay develops remains a complex task for students, particularly as regards understanding that the interactions which produce the active agent and its action upon a tooth are chemical reactions.

Keywords: mental models, tooth decay, teaching sequence

INTRODUCTION

Achieving and ensuring good oral health is an important component of children's physical, social, emotional and intellectual development (Washington State Department of Health, 2011). In Spain, oral and dental hygiene is only directly addressed in the primary curriculum, although some recent studies (Ramos, 2010) highlight a number of reasons (e.g. poor dental habits and high rates of tooth decay) why it should continue to be addressed among adolescents. In light of this research, we developed a teaching sequence on dental health and hygiene aimed at 15-16 year-old students (Blanco, Franco-Mariscal and España, 2016). This teaching sequence, which has been implemented since 2012, can be considered novel in the Spanish context, since it regards the question of oral and dental hygiene as a relevant context in which to develop students' scientific competences and to improve the dental health of the country's adolescents.

One of the ways in which we have assessed the impact of the teaching sequence consists in comparing students' mental models of tooth decay before and after their exposure to it, the rationale being that significant changes in explanatory models are one of the most important kinds of conceptual change (Lawson et al., 2000). Although mental models have attracted considerable attention among researchers and educators (Clement, 2008), this has not been the case in the field of health sciences (Cabello, España and Blanco), and to our knowledge, no studies have specifically examined students' mental models of tooth decay. Identifying these models and understanding how they develop and evolve would provide a useful platform on which to build teaching modules that could help students to understand dental caries and to improve their dental habits and health, all of which should lead to a reduction in the prevalence of tooth decay among adolescents.

METHODS

In order to identify the mental models underlying students' understanding of tooth decay we implemented two case studies across two academic years with a total of 28 students. The present study focuses on the

analysis of two tasks that formed part of a pre-test/post-test design whose aim was to determine whether students could provide an adequate explanation of the problem of dental caries. The two tasks/questions were: 1) *What factors are involved in the development of tooth decay? 2) Explain the role played by each of these factors and describe in detail how the development of tooth decay takes place*.

Mental models were identified through an iterative process that combined an examination of the nature of the concept in question with an analysis of students' responses. Dental caries may be considered under the category of scientific concepts that Chi et al. (1994) refer to as *processes*, in this case, a phenomenon that affects teeth under certain circumstances. In order to define a process (Chi et al., 1994) it is necessary to consider three questions: What material elements (or system components) are involved? What happens between them (how do they interact)?) What changes occur during the process (what kind of transformation takes place)? When it comes to identifying mental models of tooth decay, there are two key aspects that must be considered: the nature of the active agent and the mechanism by which dental caries is produced. The active agent is the entity, living organism, substance or product that acts upon teeth and produces decay. The mechanism or explanatory model accounts for the interactions between the different entities involved. In the case that concerns us here, a desirable mental model would be one based on scientific ideas and which considers the role played by bacteria, sugar and acids.

Starting from such a framework we conducted a detailed analysis of students' responses in order to identify their underlying mental models. Through their participation in the teaching sequence we expected that students would become able to incorporate both the active agents and the associated mechanisms into their understanding of tooth decay.

RESULTS

The analysis of students' responses led us to identify five different mental models (A, B, C, D and E) about tooth decay, defined according to the extent to which they reflected scientific ideas regarding the active agents and mechanisms involved in dental caries.

Models A, B and C are associated with a single active agent: the tooth, food and living organisms (including bacteria), respectively. Examples of students' responses corresponding to these models include:

"The enamel on some people's teeth is really poor and chips off really easily." (Model A)

"Sugar in food breaks down the calcium in teeth." (Model B)

"Bacteria break down teeth." (Model C)

Model D includes sugar plus a second agent, while the active agent in model E is acids:

"Tooth decay comes from a mixture of sugar and saliva, which together stain your teeth and can make a hole." (Model D)

"When sugar comes into contact with bacteria in your saliva, acid is formed and little by little this causes your tooth to wear away, forming caries." (Model E)

We also identified four mechanisms, which were not exclusive to any one model. Models A, B and C were associated with a single, simplistic mechanism in which just one agent directly attacks the tooth. The explanatory mechanism associated with models D and E involved two active agents and was more complex in that it considered both how the agent was formed (stage 1) and how it attacks the tooth (stage 2).

Table 1 shows the frequency with which the different mental models were identified, both prior to and after the teaching sequence.

Table 1. Number of students associated with each model in the pre- and post-test analysis

Model	A	B	C	D	E
Pre	6	13	9	0	0
Post	1	2	2	5	18

The results show an evolution in students' explanatory models of tooth decay following their participation in the teaching sequence. Initially, the majority of students used one of the two simplest models involving a single active agent (mainly model B), with only a few students employing the slightly more advanced model C. In the post-test analysis, however, we observed a substantial shift in the numbers of students using the different models: specifically, the large majority of students now employed either model D or model E, neither of which was observed in the pre-test analysis, with the use of the most complex model E being particularly common.

CONCLUSIONS

This study illustrates a way of identifying students' mental models of tooth decay, focusing specifically on two aspects: the active agent and the associated mechanism. The results indicate that 1) these students (aged 15-16 years) initially employed a range of mental models, none of which was complete and in some cases fell well short of a scientific account of dental caries, and 2) the teaching sequence had a notable influence on the development of students' mental models, which in the majority of cases were now much more complete and close to what would be desirable from an educational perspective. However, formulating the mechanism through which tooth decay develops remains a complex task for students, particularly as regards understanding that the interactions which produce the active agent and its action upon a tooth are chemical reactions.

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